

AMENDMENTS TO THE SPECIFICATION

Please amend the paragraph beginning on line 6 and ending on line 10 of page 14 of the Specification as follows:

According to another important aspect of the present invention, the measured changes in optical properties are correlated to concentrations of hydrogen and then used to quantify the volume of diffusible hydrogen in a particular sampled mass. In general, the measuring apparatus 10 is calibrated to first correlate a detected optical change (visible as a color change) in the sensing layer 28 to a concentration (ppm) of hydrogen in the sample volume. As illustrated in Figure 3, a linear sensor response or correlation was found for a WO₃ sensing layer 28 with a palladium layer 30 between the increase in hydrogen concentration and decrease in reflectance intensity, i.e., signal drop in nanowatts. The linear correlation of Figure 3 was developed by exposing a WO₃ sensing layer 28 and a reflector layer 30 to known quantities of hydrogen in a controlled atmosphere, i.e., synthetic air of 80% nitrogen and 20% oxygen, having a volume of approximately 0.5 liters. The sensing and reflector layers 28 and 30 were allowed to react for fifteen minutes with each hydrogen concentration (ppm), and a reflectometer was used to measure the signal drop. The response of the sensing layer 28 was found to be linear over a wide range of hydrogen concentrations, and specifically, a linear response was found when hydrogen concentrations ranged from 200 to 1000 ppm in the controlled volume. The calibration data was then converted to volumes of hydrogen (uliters) and then adjusted for the differences in calibration volume (0.5 liters, as discussed above) and sample volumes 18 of the sensor assembly 20 by multiplying the volume of hydrogen by the ratio of the sensor volume 18 to that of the calibration volume. This adjusted volume was then plotted (not shown) as a function of sensor response, i.e., signal drop, to correlate the volume of diffusible hydrogen to the signal drop detected in the sensor 28, a curve with a slope with units of uliter/nW. Significantly, the slope of this curve provides a standard conversion factor that can be applied to each sensor assembly response curve acquired from a weld material to determine a rate of diffusivity from the weld material, i.e., in units of uliter/minute,

which, in turn, can be used to determine the initial diffusible hydrogen concentration in a weld sample.

Please amend the paragraph beginning on line 6 and ending on line 25 of page 14 of the Specification as follows:

Significantly, the predictable, linear response of the sensing layer 28 and reflector layer 30 enables the sensor assembly 20 to be calibrated for determining the diffusible hydrogen in a weld sample and, further, for determining the initial diffusible hydrogen concentration in the weld sample, i.e., in the weld material. In this regard, the inventors performed a series of experiments that correlate the slope of a sensor response curve to the initial diffusible hydrogen concentration in a weld sample, such as weld bead 16. The steady state portion of a sensor response curve was assumed to be proportional to the flux, e.g., diffusivity rate, of hydrogen from the weld sample, which in turn is proportional to the initial concentration of hydrogen in the weld sample. Slopes of curves generated with the sensor assembly 20 using welded samples were found to correlate closely with quantitative results for initial diffusible hydrogen concentrations in duplicate welded samples that were analyzed using a standard method, i.e., AWS A4.3-93, for measuring diffusible hydrogen concentrations. The slopes of the generated curves from the sensor assembly 20 also closely correlated with curves developed from a theoretical diffusion equation, based on a form of the error function equation.

Please amend the paragraph beginning on line 6 and ending on line 5 of page 15 of the Specification as follows:

More specifically and with reference to Figure 4, solutions for the theoretical diffusion equation were generated for different initial diffusible hydrogen concentrations as a function of time with the results being adjusted for the average amount of weld metal per sample and multiplied by the ratio of surface area sampled, i.e., sample area 17, to total area of the welded object. The slopes of theoretical curves resulting from the equation solutions were calculated in 2 hour time intervals in units of $\mu\text{liter/minute}$ based on weld samples from gas metal arc welding of HSLA 100 steel.

Using the sensor assembly 20, response curves were then developed for a number of weld samples, the slopes of the response curves were determined, and the slopes were converted to units of $\mu\text{liter/minute}$, as described above. ~~This calibration data was then~~

~~converted to volumes of hydrogen (μ liters) and then adjusted for the differences in calibration volume (0.5 liters, as discussed above) and sample volume 18 of the sensor assembly 20 by multiplying the volume of hydrogen by the ratio of the sensor volume 18 to that of the calibration volume. Figure 4 illustrates the close correlation between the expected theoretical diffusible hydrogen concentrations and the diffusible hydrogen concentrations measured during use of the sensor assembly 20.~~

Please amend the paragraph beginning on line 6 and ending on line 19 of page 15 of the Specification as follows:

~~This adjusted volume was then plotted (not shown) as a function of sensor response, i.e., signal drop, to correlate the volume of diffusible hydrogen to the signal drop detected in the sensor 28, a curve with a slope with units of μ liter/nW. Significantly, the slope of this curve provides a standard conversion factor that can be applied to each sensor assembly response curve to determine a rate of diffusivity from the weld material, i.e., in units of μ liter/minute, which, in turn, can be used to determine the initial diffusible hydrogen concentration in a weld sample by multiplying by the time since the initial weld process was completed. As can be appreciated, the present invention is useful for quickly determining a concentration-response curve slope from concentrations of diffusible hydrogen evolving from a welded surface into the sample volume that is indicative of hydrogen diffusivity rate, correlating this measured hydrogen concentration to a volume of hydrogen per quantity of weld material, and then relating the quantified hydrogen concentration such slope back to the initial diffusible hydrogen concentration existing in the weld material immediately after weld completion according to the slopes of curves generated experimentally and/or theoretically, which, as explained above, correlated closely with initial diffusible hydrogen concentrations in duplicate welds, i.e., welds made with the same kinds of materials in the same conditions.~~

Please amend the paragraph beginning on line 6 and ending on line 19 of page 19 of the Specification as follows:

Internal calibration is achieved by introducing a precise and known amount of hydrogen into the sample volume 18 before, during, or after the measurement of hydrogen concentrations in the sample volume 18 that have evolved from the weld bead 16 for the determination of diffusible hydrogen concentrations in weld bead 16, as discussed above. For illustration purposes, but not as a limitation, the diffusible hydrogen emanating from the weld bead 16 and captured in the sample volume 18 can first be measured as discussed above and the resulting signal from the detector 68 recorded and/or stored by the signal analyzer 72. Next, a known calibration amount of hydrogen can be injected into the sample volume 18 for in situ calibration of the sensor assembly 20. The sensing layer 28 is allowed to absorb the injected calibration hydrogen for a certain period of time, e.g., 10 to 30 minutes, and then the detector 68 is operated to detect the intensity of the reflected light 67 and to transmit a signal to the signal analyzer 72. The signal analyzer 72 can be programmed to store the incremental or new intensity after the injection of the calibration hydrogen and to determine a ratio of the ~~diffusible-actual~~ hydrogen concentration signal to the incremental calibration signal. This ratio can then be multiplied by the known volume of injected calibration hydrogen to calculate the volume of the measured ~~diffusible~~ hydrogen in sample volume 18. In this manner, the internal calibration step produces more accurate measurements of evolved diffusible hydrogen in the sample volume 18 by accounting for variations in ~~temperature,~~ sample volume 18 and in temperature and sensitivity of the sensing layer 28 from one sample measurement to the next.